

CLEAN SUBSTITUTE SPECIFICATION**cGMP-PDE INHIBITORS FOR THE
TREATMENT OF ERECTILE DYSFUNCTION**

This is a divisional application of application no. 09/880,141, which is a divisional application of application no. 08/836,670 filed May 22, 1997, now US Patent 6,300,335 which is a National Phase filing under 35 USC §371 based on PCT/EP95/04066 which was filed internationally on 16 October 1995 and which was published internationally as WO 96/16644 on 6 June 1996.

This invention relates to the use of compounds which are selective inhibitors of cyclic guanosine 3',5'-monophosphate phosphodiesterases (cGMP PDEs) in the treatment of erectile dysfunction (impotence) in male animals, including man.

Impotence can be defined literally as a lack of power, in the male, to copulate and may involve an inability to achieve penile erection or ejaculation, or both. More specifically, erectile impotence or dysfunction may be defined as an inability to obtain or sustain an erection adequate for intercourse. Its prevalence is claimed to be between 2 and 7% of the human male population, increasing with age, up to 50 years, and between 18 and 75% between 55 and 80 years of age. In the USA alone, for example, it has been estimated that there are up to 10 million impotent males, with the majority suffering from problems of organic rather than of psychogenic origin.

Reports of well-controlled clinical trials in man are few and the efficacy of orally administered drugs is low. Although many different drugs have been shown to induce penile erection, they are only effective after direct injection into the penis, e.g. intraurethrally or intracavernosally (i.c.), and are not approved for erectile dysfunction. Current medical treatment is based on the i.c. injection of vasoactive substances and good results have been claimed with phenoxybenzamine, phentolamine, papaverine and prostaglandin E₁, either alone or in combination; however, pain, priapism and fibrosis of the penis are associated with the i.c. administration of some of these agents. Potassium channel openers (KCO) and vasoactive intestinal polypeptide (VIP) have also been shown to be active i.c., but cost and stability issues could limit development

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of the latter. An alternative to the i.c. route is the use of glyceryl trinitrate (GTN) patches applied to the penis, which has been shown to be effective but produces side-effects in both patient and partner.

As a general alternative to pharmacological intervention, a variety of penile prostheses has been used to assist achievement of an erection. The short term success rate is good, but problems with infection and ischaemia, especially in diabetic men, make this type of treatment a final option rather than first-line therapy.

According to the specification of our International patent application no PCT/EP94/01580, (publication no WO94/28902), we describe and claim the use of a series of pyrazolo [4,3-d]pyrimidin-7-ones for the treatment of impotence. The compounds are potent and selective inhibitors of cGMP PDE in contrast to their inhibition of cyclic adenosine 3',5'-monophosphate phosphodiesterases (cAMP PDEs). This selective enzyme inhibition leads to elevated cGMP levels which, in turn, provides the basis for the utilities previously disclosed for the compounds in the treatment of stable, unstable and variant (Prinzmetal) angina, hypertension, pulmonary hypertension, congestive heart failure, atherosclerosis, conditions of reduced blood vessel patency, peripheral vascular disease, stroke, bronchitis, allergic asthma, chronic asthma, allergic rhinitis, glaucoma, and diseases characterised by disorders of gut motility, e.g. irritable bowel syndrome. The specification goes on to describe investigations which identified three PDE isoenzymes in human corpus cavernosum tissue, relaxation of which leads to penile erection. The predominant enzyme was found to be the cGMP-specific PDE_v, while cGMP-stimulated cAMP PDE_{ii} and cGMP-inhibited cAMP PDE_{iii}, were also present. The compounds described were found to be potent and selective inhibitors of the PDE_v enzyme but demonstrated only weak inhibitory activity against the PDE_{ii} and PDE_{iii} enzymes. This activity is believed to be responsible for the action of the compounds in the treatment of erectile dysfunction.

A number of cGMP-PDE inhibitors have previously been described in the literature for a variety of utilities, these include use in treating obstructive lung diseases such as asthma and bronchitis, in combatting allergic diseases such as allergic asthma, allergic rhinitis, urticaria, and irritable bowel syndrome; and in combatting angina, hypertension and congestive heart failure. Utility has also

been claimed as diuretics, as antiinflammatory agents, in the treatment of baldness, for conditions of reduced blood vessel patency, and in glaucoma. However there has not previously been any suggestion that any of these compounds would be of utility in the treatment of erectile dysfunction.

Thus the present invention provides the use of a compound which is a selective cGMP PDE inhibitor for the manufacture of a medicament for the treatment of erectile dysfunction in a male animal, including man, wherein said compound is:

- i a 5-substituted pyrazolo [4,3-d]pyrimidine-7-one as disclosed in European patent application 0201188;
- ii a griseolic acid derivative as disclosed in European patent applications nos 0214708 and 0319050;
- iii a 2-phenylpurinone derivative as disclosed in European patent application 0293063;
- iv a phenylpyridone derivative as disclosed in European patent application 0347027;
- v a fused pyrimidine derivative as disclosed in European patent application 0347146;
- vi a condensed pyrimidine derivative as disclosed in European patent application 0349239;
- vii a pyrimidopyrimidine derivative as disclosed in European patent application 0351058;
- viii a purine compound as disclosed in European patent application 0352960;
- ix a quinazolinone derivative as disclosed in European patent application 0371731;
- x a phenylpyrimidone derivative as disclosed in European patent application 0395328;
- xi an imidazoquinoxalinone derivative or its aza analogue as disclosed in European patent application 0400583;
- xii a phenylpyrimidone derivative as disclosed in European patent application 0400799;
- xiii a phenylpyridone derivative as disclosed in European patent application 0428268;
- xiv a pyrimidopyrimidine derivative as disclosed in European patent 0442204;

- xv a 4-aminoquinazoline derivative as disclosed in European patent application 0579496;
- xvi a 4,5-dihydro-4-oxo-pyrrolo[1,2-a]quinoxaline derivative or its aza analogue as disclosed in European patent application 0584487;
- xvii a polycyclic guanine derivative as disclosed in International patent application WO91/19717;
- xviii a nitrogenous heterocyclic compound as disclosed in International patent application WO93/07124;
- xix a 2-benzyl-polycyclic guanine derivative as disclosed in International patent application WO 94/19351;
- xx a quinazoline derivative as disclosed in US patent 4060615;
- xxi a 6-heterocyclyl pyrazolo [3,4-d]pyrimidin-4-one as disclosed in US patent 5294612;
- xxii a benzimidazole as disclosed in Japanese patent application 5-222000; or
- xxiii a cycloheptimidazole as disclosed in European Journal of Pharmacology, 251, (1994), 1.
- xxiv a N-containing heterocycle as disclosed in International patent application WO94/22855.

The invention includes the use of any compound within the scope of the claims of the patents listed above as well as the particular individual compounds disclosed therein.

Of particular interest for use in the present invention are compounds disclosed in EP 0579496, WO93/07124, US 5294612 and WO94/22855 (xv, xviii, xxi and xxiv above); the compounds of EP 0579496 and WO94/22855 being especially preferred.

Examples of particular and preferred compounds from these patents and publications for use in the present invention include:

1,3-dimethyl-5-benzylpyrazolo[4,3-d]pyrimidine-7-one (preparation as described in European patent application 201188, Example 1),
2-(2-propoxyphenyl)-6-purinone (preparation as described in European patent application 0293063, Example 1),

6-(2-propoxyphenyl)-1,2-dihydro-2-oxopyridine-3-carboxamide (preparation as described in European patent application 0347027, Example 2),
 2-(2-propoxyphenyl)pyrido[2,3-d]pyrimidin-4(3H)-one (preparation as described in European patent application 0347146, Example 1),
 7-methylthio-4-oxo-2-(2-propoxyphenyl)-3,4-dihydropyrimido[4,5-d]pyrimidine (preparation as described in European patent application 0351058, Example 1),
 6-hydroxy-2-(2-propoxyphenyl)pyrimidine-4-carboxamide (preparation as described in European patent application 0395328, Example 15),
 1-ethyl-3-methylimidazo[1,5a]quinoxalin-4(5H)-one (preparation as described in European patent application 0400583),
 4-phenylmethylamino-6-chloro-2-(1-imidazolyl)quinazoline (preparation as described in European patent application 0579496, Example 5(c)),
 5-ethyl-8-[3-(N-cyclohexyl-N-methylcarbamoyl)-propyloxy]-4,5-dihydro-4-oxo-pyrido[3,2-e]pyrrolo[1,2-a]pyrazine (preparation as described in European patent application 0584487, Example 1),
 5'-methyl-3'-(phenylmethyl)-spiro[cyclopentane-1,7'(8'H)-(3'H)-imidazo[2,1-b]purin]4'(5'H)-one (preparation as described in International patent application WO 91/19717, Example 9A3),
 1-[6-chloro-4-(3,4-methylenedioxybenzyl)aminoquinazolin-2-yl]piperidine-4-carboxylic acid (preparation as described in International patent application WO93/07124),
 (6aR,9aS)-2-(4-trifluoromethylphenyl)methyl-5-methyl-3,4,5,6a,7,8,9,9a-octahydrocyclopent[4,5]imidazo[2,1-b]purin-4-one (preparation as described in International Patent application WO94/19351, Example 14),
 1-tert-butyl-3-phenylmethyl-6-(4-pyridyl)pyrazolo[3,4-d]pyrimidin-4-one (preparation as described in US patent 5294612, Example 90),
 1-cyclopentyl-3-methyl-6-(4-pyridyl)-4,5-dihydro-1H-pyrazolo[3,4-d]pyrimidin-4-one, (preparation as described in US patent 5294612, Example 83),
 2-butyl-1-(2-chlorobenzyl)6-ethoxycarbonylbenzimidazole (preparation described in Japanese patent application 5-222000),
 2-(4-carboxypiperidino)-4-(3,4-methylenedioxybenzyl)amino-6-nitroquinazoline (preparation described in International patent application WO94/22855, Example II),
 and 2-phenyl-8-ethoxycycloheptimidazole (KT2-734).

Of particular interest for use in the present invention are the compounds:
 4-phenylmethylamino-6-chloro-2-(1-imidazolyl)quinazoline (preparation as described in European patent application 0579496, Example 5(c)),
 1-[6-chloro-4-(3,4-methylenedioxybenzyl)aminoquinazolin-2-yl]piperidine-4-carboxylic acid (preparation as described in International patent application WO93/07124),
 (6aR,9aS)-2-(4-trifluoromethylphenyl)methyl-5-methyl-3,4,5,6a,7,8,9,9a-octahydrocyclopent[4,5]imidazo[2,1-b]purin-4-one (preparation as described in International Patent application WO94/19351, Example 14),
 1-tert-butyl-3-phenylmethyl-6-(4-pyridyl)pyrazolo[3,4-d]pyrimid-4-one (preparation as described in US patent 5294612, Example 90),
 1-cyclopentyl-3-methyl-6-(4-pyridyl)-4,5-dihydro-1H-pyrazolo[3,4-d]pyrimid-4-one, as described in US patent 5294612, Example 83), or
 2-(4-carboxypiperidino)-4-(3,4-methylenedioxybenzyl)amino-6-nitroquinazoline (preparation described in International patent application WO94/22855, Example II),

Further cGMP PDE inhibitors for use in the treatment of erectile dysfunction are:

- xxv a pyrazolopyrimidine derivative as disclosed in European patent application 0636626;
- xxvi a 4-aminopyrimidine derivative as disclosed in European patent application 0640599;
- xxvii a imidazoquinazoline derivative as disclosed in International patent application WO95/06648;
- xxviii an anthranilic acid derivative as disclosed in International patent application WO95/18097;
- xxix a 4-aminoquinazoline derivative as disclosed in US patent 5436233;
- xxx a tetracyclic derivative as disclosed in International patent application WO95/19978;
- xxxi a imidazoquinazoline derivative as disclosed in European patent application 0668280; or
- xxxii a quinazoline compound as disclosed in European patent application 0669324.

The compounds may be evaluated as selective inhibitors of cGMP-PDE using any of the methods previously described but in particular their activity against cGMP-PDE_v may be assessed as described in our International patent application PCT/EP94/01580, (WO94/28902).

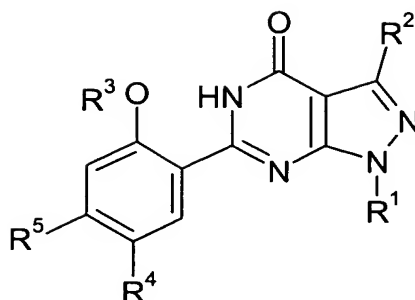
Generally, in man, oral administration is the preferred route, being the most convenient and avoiding the disadvantages associated with i.c. administration. A preferred dosing regimen for a typical man is 5 to 75 mg of compound daily, however the dosage may be increased depending on the potency of the compound being administered and higher dosages are within the scope of the invention. Alternative dosage regimes are also possible depending upon the individual patients circumstances such as the frequency of sexual intercourse. In circumstances where the recipient suffers from a swallowing disorder or from impairment of drug absorption after oral administration, the drug may be administered parenterally, e.g. sublingually or buccally.

For veterinary use, a compound of the invention or a non-toxic salt thereof is administered as a suitably acceptable formulation in accordance with normal veterinary practice and the veterinary surgeon will determine the dosing regimen and route of administration which will be most appropriate for a particular male animal.

Although the compounds of the invention are envisaged primarily for the treatment of erectile dysfunction or male sexual dysfunction, they are also useful for the treatment of female sexual dysfunction including orgasmic dysfunction related to clitoral disturbances, premature labour and dysmenorrhea.

The invention also provides a method of treating erectile dysfunction in a male animal which comprises administering an effective amount of a compound which is a selective cGMP-PDE inhibitor as defined above.

As stated above, one of the groups of compounds of selective cGMP PDE inhibitors is a pyrazolopyrimidine derivative as disclosed in EP 0636626. This document discloses a compound of the formula:



and salts and solvates (e.g. hydrates) thereof, in which:

R^1 represents arylmethyl or C_{1-6} alkyl optionally substituted by one or more fluorine atoms;

R^2 represents methyl;

R^3 represents C_{2-4} alkyl;

R^4 represents nitro, cyano, C_{1-6} alkoxy, $C(=X)NR^6R^7$, $(CH_2)_mNR^{10}C(=Y)R^{11}$ or a 5-membered heterocyclic ring selected from thienyl, thiazolyl and 1,2,4-triazolyl each ring optionally substituted by a C_{1-4} alkyl or aryl group; or when R^1 is arylmethyl or C_{1-6} alkyl substituted by one or more fluorine atoms then R^4 may also represent hydrogen;

R^5 represents hydrogen or C_{1-6} alkyl;

R^6 represents hydrogen or C_{1-6} alkyl;

R^7 represents hydrogen, amino, hydroxyl, C_{1-6} alkyl, aryl or aryl C_{1-4} alkyl;

R^8 represents hydrogen or C_{1-6} alkyl;

R^9 represents hydrogen, C_{1-6} alkyl, SO_2R^{12} , CO_2R^{12} , $C(=NCN)SR^{12}$ or $C(=NCN)NR^{13}R^{14}$;

R^{10} represents hydrogen or C_{1-6} alkyl;

R^{11} represents C_{1-6} alkyl optionally substituted by one or more halogen atoms, or R^{11} represents aryl, aryl C_{1-4} alkyl, thienyl, $NR^{15}R^{16}$, $CH_2NR^{17}R^{18}$ or R^{10} and R^{11} together represent $A(CH_2)_n$;

R^{12} represents C_{1-6} alkyl, aryl or aryl C_{1-4} alkyl;

R^{13} represents hydrogen or C_{1-6} alkyl;

R^{14} represents hydrogen, C_{1-6} alkyl, aryl, aryl C_{1-4} alkyl or R^{13} and R^{14} together with the nitrogen atom to which they are attached form a morpholine, piperazine or N- C_{1-4} alkylpiperazine ring;

R^{15} represent hydrogen or C_{1-6} alkyl or R^{10} and R^{15} together represent $A(CH_2)_n$;

R^{16} represents hydrogen, C_{1-6} alkyl, aryl, aryl C_{1-4} alkyl, CO_2R^{12} , $CH_2CO_2R^{12}$ or R^{15} and R^{16} together with the nitrogen atom to which they are attached form a morpholine, piperazine or N- C_{1-4} alkylpiperazine ring;

R^{17} represents hydrogen or C_{1-6} alkyl;

R^{18} represents hydrogen, C_{1-6} alkyl, aryl, aryl C_{1-4} alkyl, COR^{12} or R^{17} and R^{18} together with the nitrogen atom to which they are attached form a morpholine, piperazine or N- C_{1-4} alkylpiperazine ring;

A represents CH_2 or $C=O$;

m represents zero or 1;

n represents 1,2 or 3;

X represents S or NH, or when R7 represents amino then X may also represent O;

Y represents O or S.

The reader is referred to the original European patent document for a complete discussion and disclosure of syntheses, representative compounds, and so forth, falling within its scope.